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Describing to preserve – three new species of *Xangoniscus* (Oniscidea, Styloniscidae) of unprotected caves in dry areas from Bahia state, northeastern Brazil

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Abstract

Three new troglobitic amphibious species of *Xangoniscus* (Styloniscidae) have been described from limestone caves of the Bambui Group semiarid ecosystems (Chacoan subregion) in the state of Bahia: *Xangoniscus antiquus* **sp. nov.**, *X. chaimowiczi* **sp. nov.**, and *X. jonasi* **sp. nov.** Natural history information is provided for *X. chaimowiczi* **sp. nov.** and *X. jonasi* **sp. nov.** Considering the differences between the known species of *Xangoniscus* and those described in this study, we redefined the diagnostic characteristics of the genus. Moreover, the distribution of *Xangoniscus* is discussed. The species described in this study, along with those previously reported, serve as fundamental tools for decision-making processes aimed at conserving Brazil's speleological natural heritage.

Keywords

Amphibious Oniscidea, Cerrado, Caatinga, troglobitic, woodlice

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Introduction

Terrestrial isopods (Oniscidea) are among the most diverse groups within the order Isopoda, comprising more than 4,000 species across 38 or 39 families in more than 500 genera (Javidkar et al. 2015; Sfenthourakis and Taiti 2015; Dimitriou et al. 2019). These organisms have adapted to a wide range of terrestrial environments, from tropical forests to deserts, and from the supralittoral zone to mountain forests (Schmalfuss 2003; López-Orozco et al. 2022). Additionally, a significant number of species inhabit caves, and from an ecological-evolutionary perspective, they are classified as either troglophilous (facultative cave dwellers) or troglobitic (restricted to cave habitats) (Taiti 2004; Taiti and Gruber 2008; Bedek et al. 2011; Taiti and Xue 2012; Tabacaru and Giurginca 2013; Reboleira et al. 2015; Campos-Filho et al. 2014, 2023a, 2023b).

In Brazil, more than 50% of terrestrial isopod species are found in caves, highlighting the significant potential of this subterranean habitat (Campos-Filho et al. 2014, 2015, 2016, 2018, 2019, 2020, 2022a, 2022b, 2022c, 2023a, 2023b; Souza et al. 2015; Cardoso et al. 2020a, 2020b, 2021, 2023; Cardoso and Ferreira 2023a, 2023b; López-Orozco et al. 2024a, 2024b). To date, over 230 species have been identified, of which more than 40 are considered troglobitics, belonging to the families Armadillidae, Philosciidae, Pudeoniscidae, Scleropactidae, and Styloniscidae (Campos-Filho et al. 2014, 2019, 2020, 2022a, 2022b, 2022c, 2023a, 2023b; Bastos-Pereira et al. 2017, 2022; Cardoso et al. 2020a, 2020b, 2021, 2023; Cardoso and Ferreira 2023a, 2023b; López-Orozco et al. 2024a, 2024b).

Within the Oniscidea, the family Styloniscidae comprises 128 species in 17 genera, exhibiting a broad distribution and inhabiting a wide range of terrestrial environments, including caves (Schmalfuss 2003; Boyko et al. 2024). Of these genera, nine have been recorded in Brazil: *Chaimowiczia* Cardoso, Bastos-Pereira, Souza & Ferreira, 2021, *Clavigeroniscus* Arcangeli, 1930, *Cordioniscus* Gräeve, 1914, *Cylindroniscus* Arcangeli, 1929, *Iuiuniscus* Souza, Ferreira & Senna, 2015, *Pectenoniscus* Andersson, 1960, *Spelunconiscus* Campos-Filho, Araujo & Taiti, 2014, *Styloniscus* Dana, 1852, and *Xangoniscus* Campos-Filho, Araujo & Taiti, 2014. This represents over 50% of the global generic diversity within the family.

In the present work, three new species of *Xangoniscus* are described from caves in the state of Bahia, northeastern Brazil. We also discuss aspects of the morphology, distribution, and conservation of the species in the genus.

Material and methods

Study area

The specimens were collected from three limestone caves of the Bambui Geomorphological Group located in the southwest of the state of Bahia, between the Caatinga and Cerrado (savannah-like) biomes (Fig. 1). This area is characterised by a dry tropical

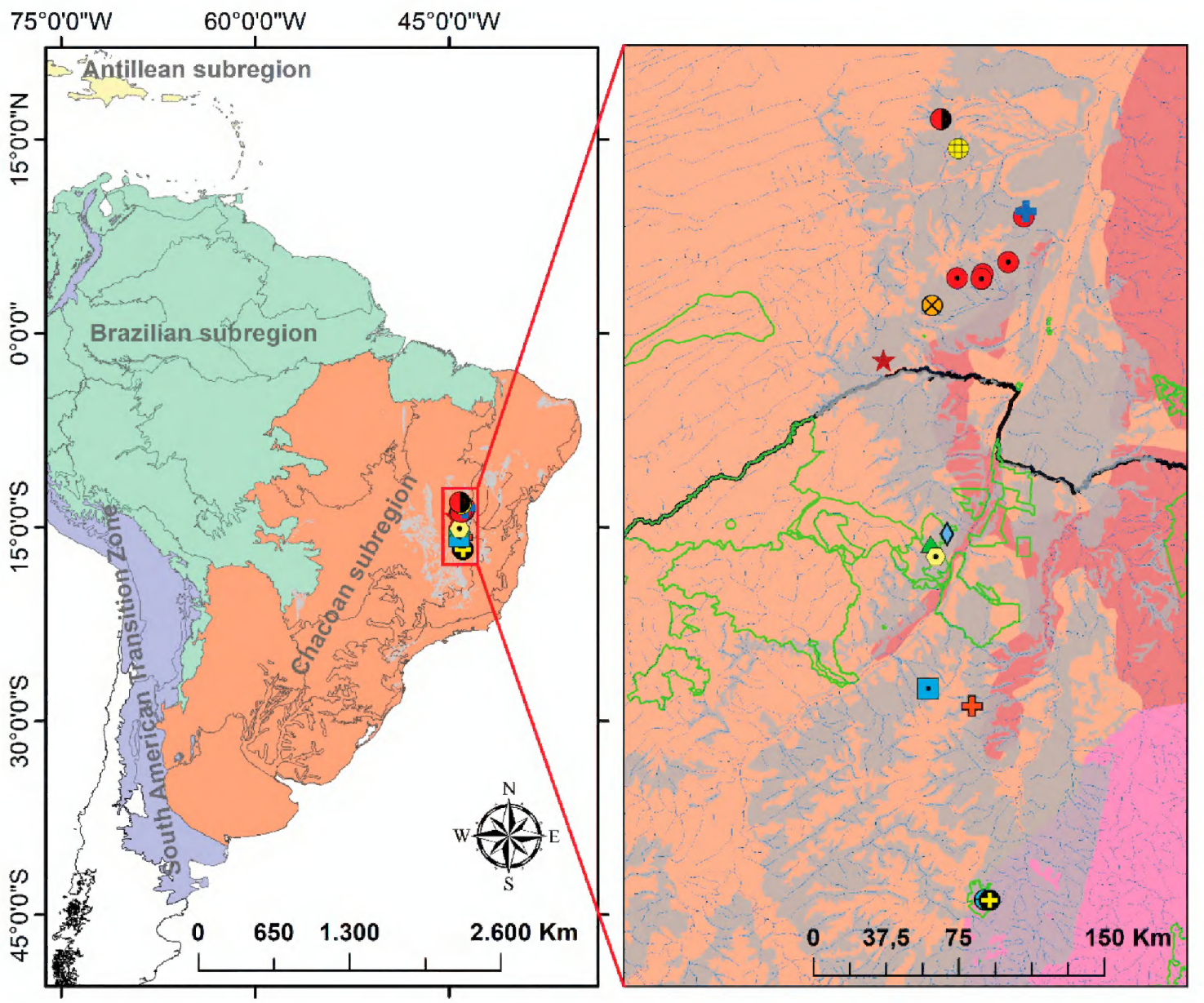

Figure 1. Map of the study area and distribution of the *Xangoniscus* species.

climate (Aw) with an average annual rainfall of up to 640 mm (Alvares et al. 2013; Beck et al. 2018, 2020).

The Gruna da Serra Solta cave (Fig. 2), is located in the Serra do Ramalho karst area, considered a hotspot of subterranean biodiversity (Trajano et al. 2016); however, there are no legal protection zones for these systems, which are threatened due to deforestation for the establishment of crops, extraction of wood, plus potential mining projects (Gallão and Bichuette 2018). To the north of the Serra do Ramalho, there is the Gruta do Padre and Gruta da Represa caves (Fig. 1). Gruta do Padre is located between the municipalities of Santana and Santa Maria da Victoria and represents one of the

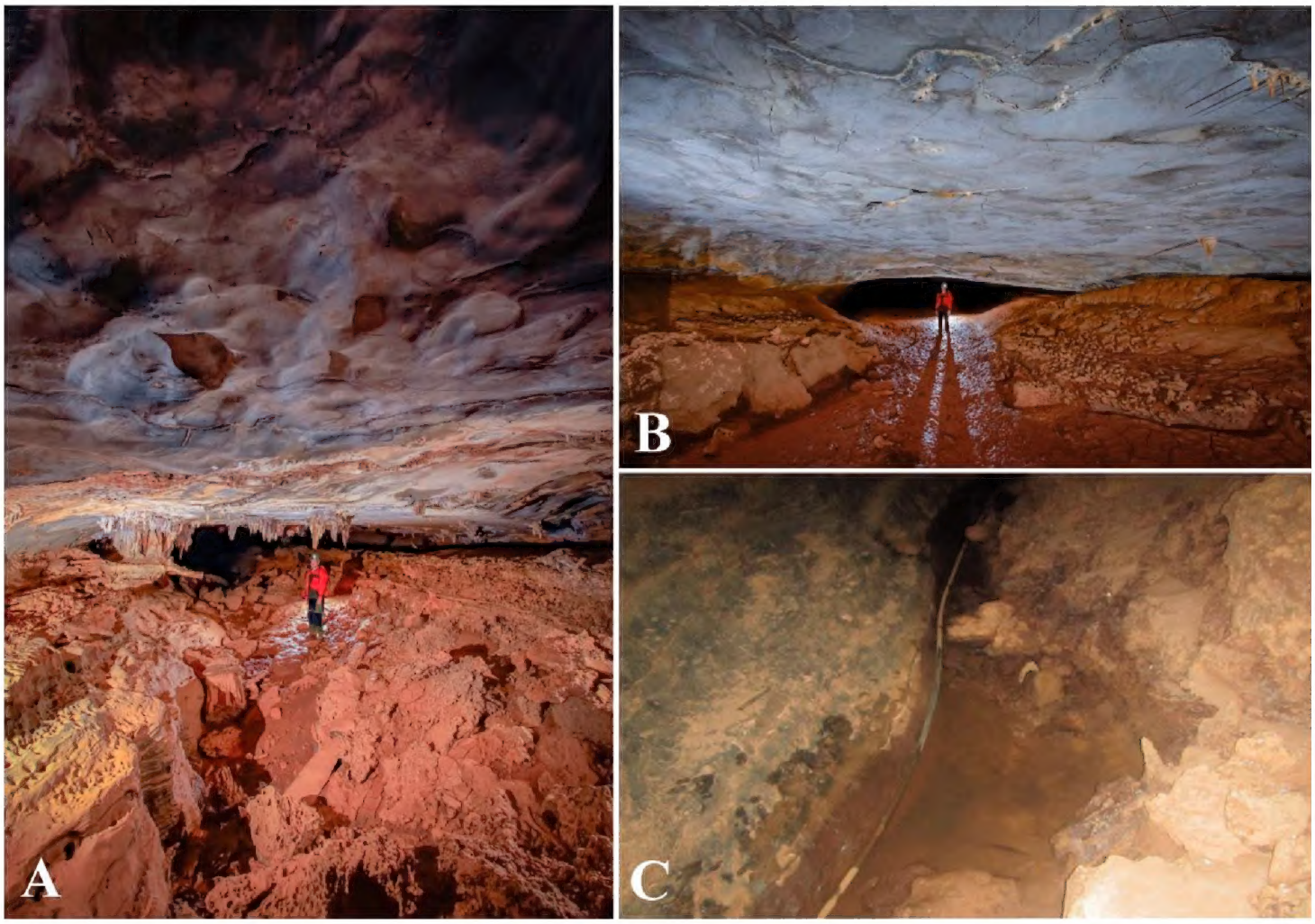

Figure 2. Gruna da Serra Solta **A, B** gallerys of the Gruna da Serra Solta **C** hose for extracting water inside the cave. Photo: Alexandre Lobo.

largest caves in Brazil (16.4 km). This cave has two known entrances, is characterised by its dry environment, and has been the scene of multiple speleological explorations (Auler and Rubbioli 2019).

Specimen preparations and taxonomy

Specimens were collected by hand and stored in 75% ethanol, and identifications were based on morphological characteristics using micropreparations in Hoyer's medium (Anderson 1954). For each new species, the type material, diagnosis, description, etymology, distribution, and remarks are provided. The subterranean classification followed Trajano and Carvalho (2017). Descriptions and morphological terms follow Campos-Filho et al. (2014). The images of each species were obtained with a stereomicroscope Nikon SMZ800N with an adapted Prime Life Science camera and edited using GIMP (v. 2.8). Illustrations were made with the aid of a camera lucida mounted on a Zeiss Stemi SV6 stereomicroscope and Leica DMLS microscope. The final illustrations were prepared using GIMP (v. 2.8), using the method proposed by Montesanto (2015, 2016).

The material examined is deposited in the Collection of the Laboratório de Estudos Subterrâneos (LES, curator: M. E. Bichuette), Universidade Federal de São Carlos, São Carlos, Brazil, and in the collection of the Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil (MZUSP, curator: Marcos Tavares).

Results

Systematic account

Suborder Oniscidea Latreille, 1802
Family Styloniscidae Vandel, 1952

Genus *Xangoniscus* Campos-Filho, Araujo & Taiti, 2014

Type species. *Xangoniscus aganju* Campos-Filho, Araujo & Taiti, 2014 by original designation and monotypy.

***Xangoniscus chaimowiczi* López-Orozco, Borja-Arrieta & Campos-Filho, sp. nov.**
https://zoobank.org/72A41F39-A8EF-4961-8BA8-B5E52EE0ADE3
Figs 1, 3–6

Type material. ***Holotype*** • 1 male (MZUSP 29529), Bahia, Santana, Gruta do Padre cave, -13.216325, -44.065194, Sala dos Anfipodes, July 1987, leg. F. Chaimowicz. ***Paratypes*** • 1 male (parts in slides), 1 male (MZUSP 29529), same data as holotype • 2 males (MZUSP 29429), same data as holotype • 1 male (MZUSP 29565), sedimentos do conduto das plaquetas (no rio), same data as holotype • 4 males (MZUSP 29540), rio dos Travertinos, same data as holotype • 2 males, 1 female (MZUSP 29421), Conduto Biógeo, same data as holotype.

Description. Maximum body length: male 10.2 mm, female 6.5 mm. Body outline as in Figs 3A, B, 4A. Colourless (Fig. 3). Dorsal surface smooth, with scattered fringed scale setae (Figs 3A, B, 4A, B). Cephalon (Figs 3C, 4C) with large quadrangular antennary lobes; vertex with slightly lateral depression to fit antennae when extended backward, profrons with V-shaped suprantennal line, not surpassing antennule insertion; eyes absent. Pereonite 1 epimera with distal corners developed frontwards, posterior corners right-angled; pereonites 2–7 epimera gradually directed backward posterior corners progressively more acute (Figs 3A, B, 4A); pleon narrower than pereon; pleonites 3–5 epimera posterior point not developed (Figs 3D, 4A). Telson with concave sides and rounded apex (Fig. 4D). Antennula (Fig. 4E) composed of three articles, proximal and distal articles subequal in length, second article shortest, and distal article with 12 long aesthetascs. Antenna (Fig. 4F) short, not surpassing pereonite 2 when extended backward; flagellum shorter than fifth article of peduncle, with three articles subequal in length. Left mandible (Fig. 4G) with two penicils; right mandible (Fig. 4H) with one penicil. Maxillula (Fig. 4I) inner endite with three penicils; outer endite with 5+5 teeth, apically simple, and two plumose stalks. Maxilla (Fig. 4J) with setose and bilobate apex, outer lobe smaller. Maxilliped (Fig. 4K) basis enlarged on distal portion bearing fringe of fine setae; first article of palp with two tiny setae, distal articles with three tufts of setae; endite rectangular, outer and medial margins setose, apically with two triangular teeth and large rounded penicil. Uropod (Fig. 4D) branches short and inserted at same level, exopod slightly longer than endopod. Pereopods 1–7

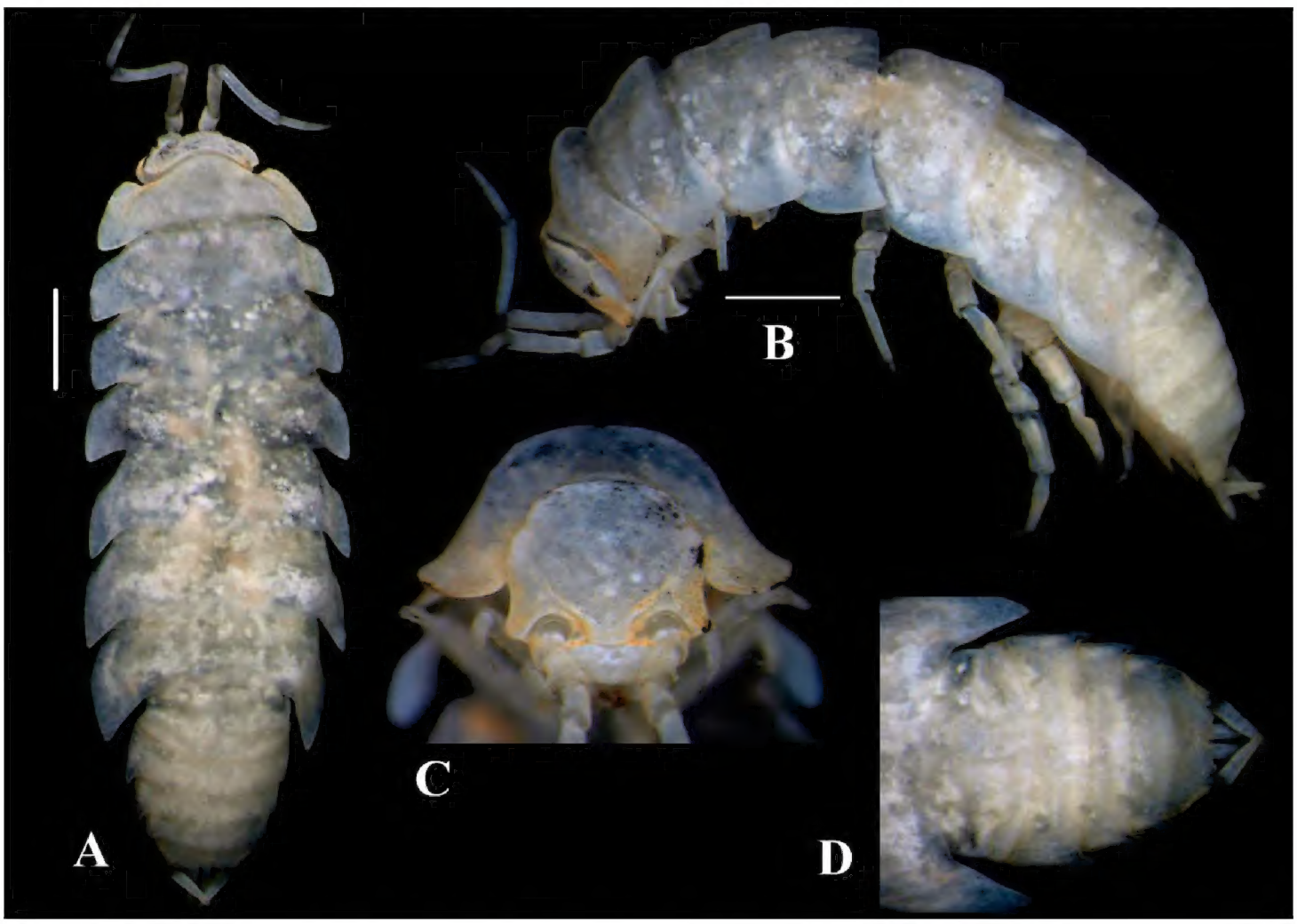

Figure 3. *Xangoniscus chaimowiczi* López-Orozco, Borja-Arrieta & Campos-Filho, sp. nov. Male **A** habitus, dorsal view **B** habitus, lateral view **C** cephalon and pereonite 1, frontal view **D** pereonite 7, pleon and telson, dorsal view. Scale bars: 1 mm.

(Fig. 5A–G) gradually elongated, with merus, carpus, and propodus bearing sparse setae; dactylus of one claw bearing many setae on outer margin.

Male. Pereopods 1–6 (Fig. 5A–F) merus with proximal portion bearing fringed scales and thin setae on sternal margin. Pereopod 1 (Fig. 5A) carpus with large antennal grooming brush. Pereopod 5 (Fig. 5E) carpus with slightly lobe on proximal sternal margin. Pereopod 6 (Fig. 5F) ischium enlarged with flattened sternal part; carpus enlarged, rostral portion bearing dense field of tiny lobules; propodus with central part enlarged, with longitudinal furrow in ventral view, and very tiny setae in dorsal. Pereopod 7 (Fig. 5G) without distinct modifications. Genital papilla (Fig. 6A) lanceolate. Pleopod 1 (Fig. 6A) exopod subtriangular, longer than wide, inner and outer margins bearing fringe of fine setae; endopod longer than exopod, with narrow basal article and flagelliform distal article; basipod distal margin elongate and acute apex, longer than exopod, with fine and long setae. Pleopod 2 (Fig. 6B) exopod trapezoidal, distal margin slightly convex; endopod of two articles, distal article about three times as long as proximal, with distal margin subquadrangular and apex rounded, with transversal process in V-like on apex in ventral view. Pleopod 3 (Fig. 6C) exopod triangular, longer than wide, covering pleopods 1 and 2, fringed with short setae. Pleopod 4 and 5 (Fig. 6D, E) exopods trapezoidal, wider than long, with margins bearing several short setae.

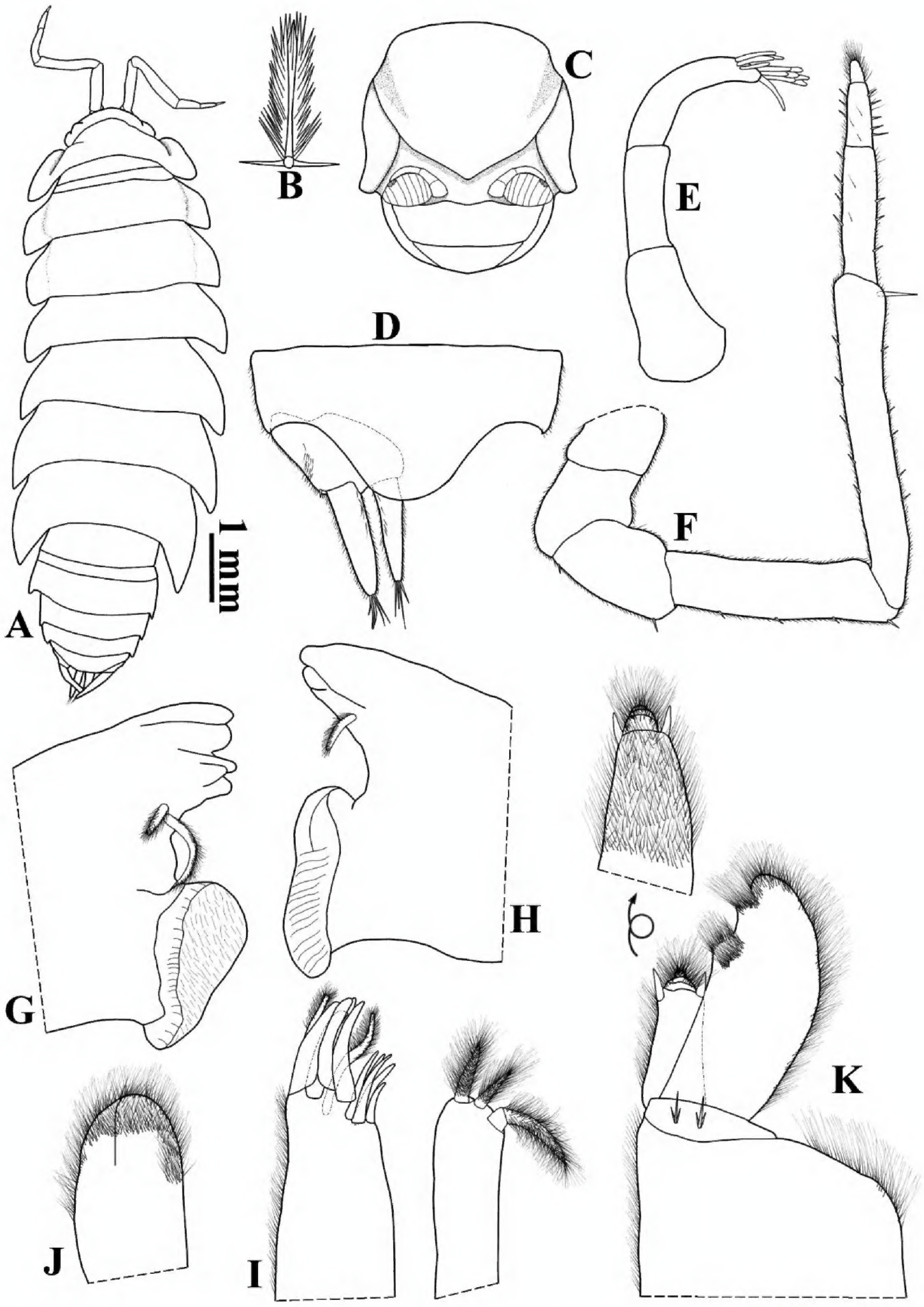

Figure 4. *Xangoniscus chaimowiczi* López-Orozco, Borja-Arrieta & Campos-Filho, sp. nov. Male **A** habitus, dorsal view **B** dorsal scale-seta **C** cephalon, frontal view **D** telson and uropod **E** antennula **F** antenna **G** left mandible **H** right mandible **I** maxillula **J** maxilla **K** maxilliped, arrow illustrating the endite in caudal view.

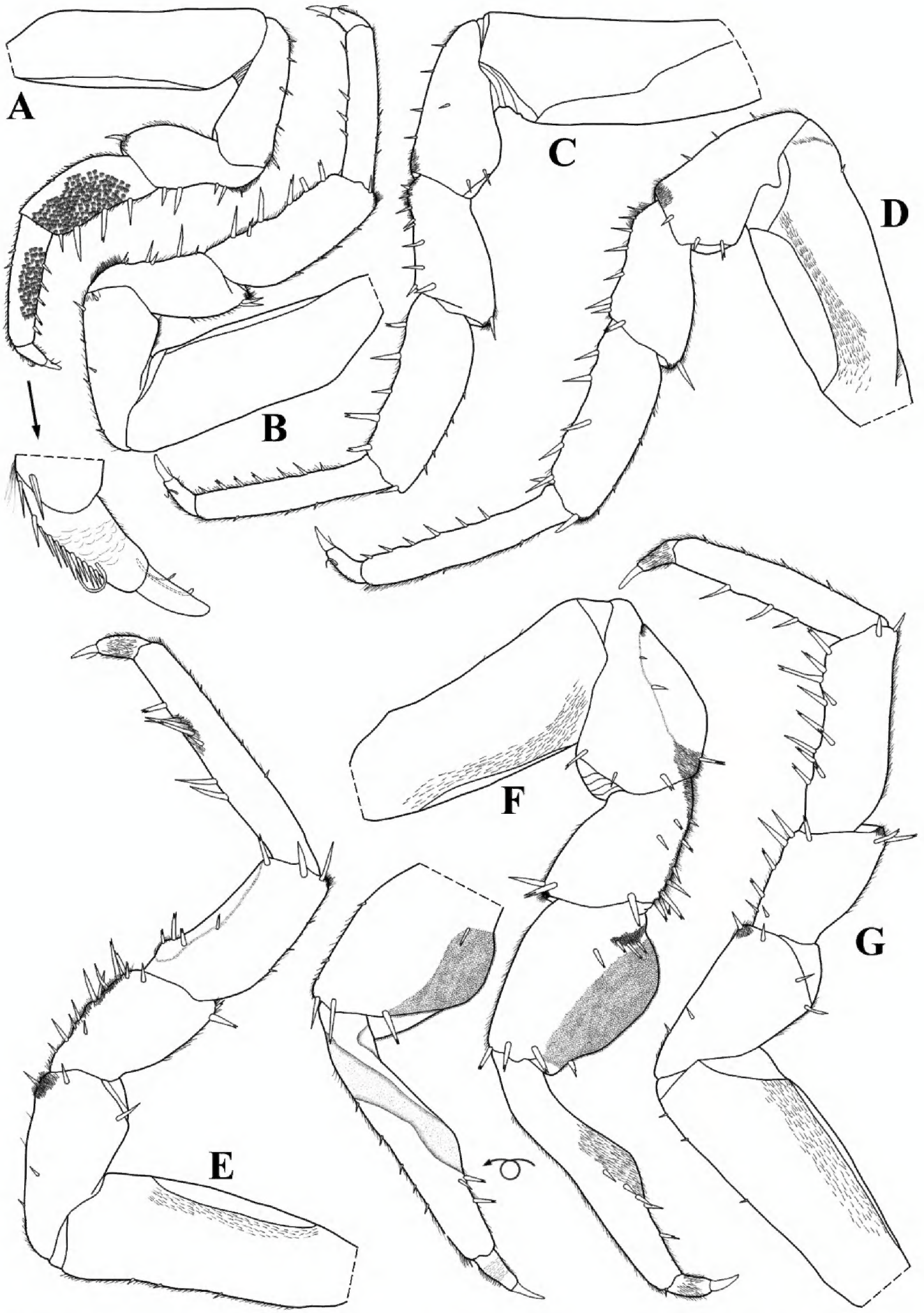

Figure 5. *Xangoniscus chaimowiczi* López-Orozco, Borja-Arrieta & Campos-Filho, sp. nov. Male **A** pereopod 1 **B** pereopod 2 **C** pereopod 3 **D** pereopod 4 **E** pereopod 5 **F** pereopod 6 **G** pereopod 7.

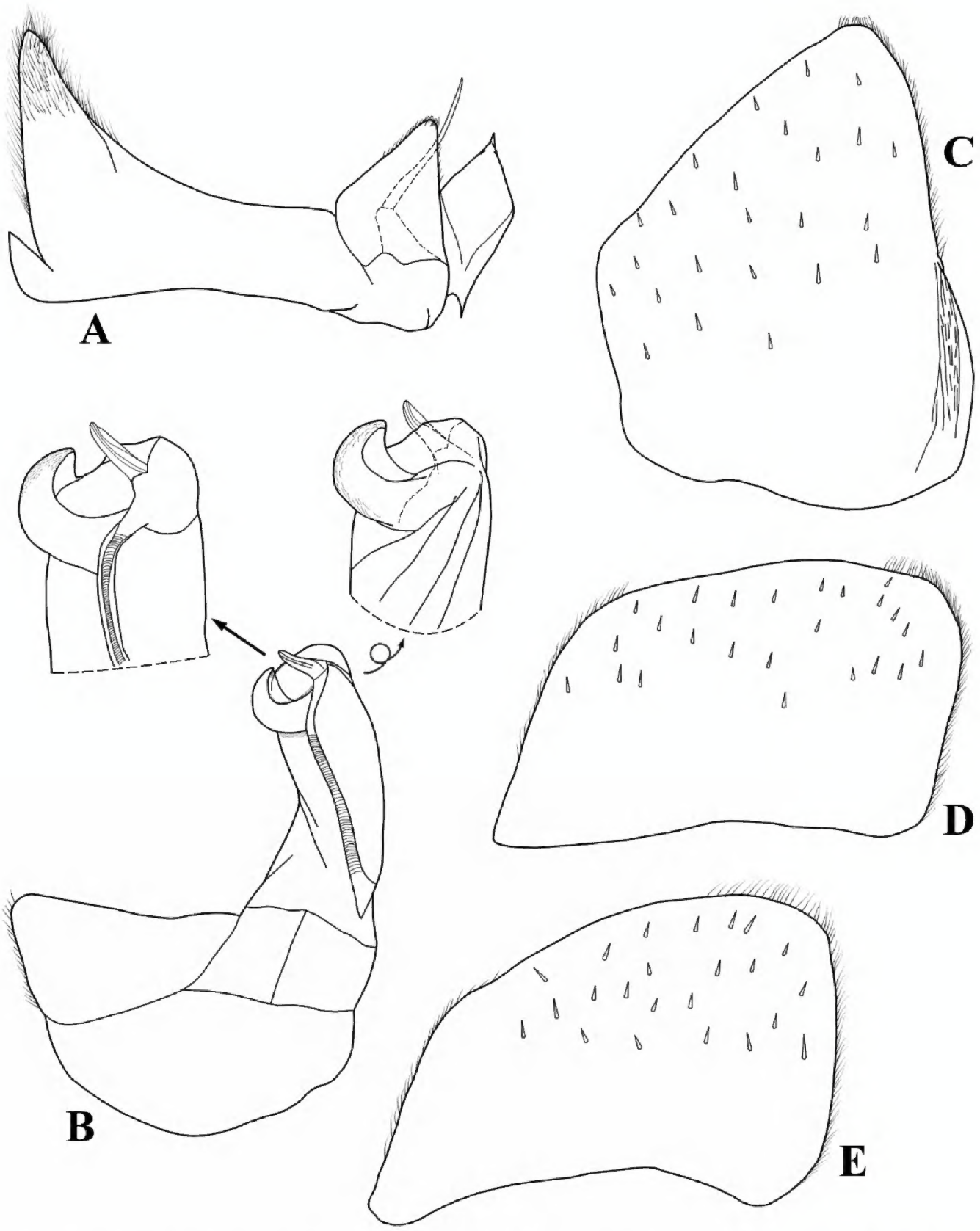

Figure 6. *Xangoniscus chaimowiczi* López-Orozco, Borja-Arrieta & Campos-Filho, sp. nov. Male **A** pleopod 1 and genital papilla **B** pleopod 2 **C** pleopod 3 exopod **D** pleopod 4 exopod **E** pleopod 5 exopod.

Etymology. The new species is named after Dr. Flavio Chaimowicz, for his important contributions to the knowledge of the Brazilian speleology, who collected the specimens.

Distribution. Presently known only from Gruta do Padre cave in the state of Bahia, northeastern Brazil (Fig. 1).

Remarks. The genus *Xangoniscus* includes 10 amphibious troglobitic species, with a distribution restricted to caves of the Bambui Geomorphological Group between the northeast and southeast regions of Brazil in the states of Bahia and Minas Gerais. Currently, the genus is well defined morphologically, and the main characteristic is the complex shape of the apex of the endopod of pleopod 2 in males. *Xangoniscus chaimowiczi* sp. nov. differs from all other species of the genus in having the antennula with twelve long aesthetascs (*vs.* two in *X. aganju* Campos-Filho, Araujo & Taiti, 2014, *X. lapaensis* Campos-Filho, Gallo & Bichuette, 2022, and *X. odara* Campos-Filho, Bichuette & Taiti, 2016, three in *X. ibiracatuensis* Bastos-Pereira, Souza & Ferreira, 2017, *X. lundi* Cardoso, Bastos-Pereira, Souza & Ferreira, 2020, and *X. santinhoi* Cardoso, Bastos-Pereira, Souza & Ferreira, 2020, four in *X. dagua* Cardoso, Bastos-Pereira, Souza & Ferreira, 2020, four or five in *X. ceci* Cardoso, Bastos-Pereira, Souza & Ferreira, 2020, five in *X. loboi* Campos-Filho, Gallão & Bichuette, 2022, six in *X. itacarambiensis* Bastos-Pereira, Souza & Ferreira, 2017), pereopod 5 carpus with tiny lobe in proximal margin (*vs.* absent in all species), pereopod 6 carpus enlarged (*vs.* not enlarged in all species), and pereopod 6 propodus with longitudinal furrow (*vs.* absent in all species) (Campos-Filho et al. 2015, 2022b; Bastos-Pereira et al. 2017; Cardoso et al. 2020).

Natural history. *Xangoniscus chaimowiczi* sp. nov. inhabits various areas of the Gruta do Padre cave. Specimens were collected from the river, specifically within the conducto das plaquetas, where they were found living in the sediment. It also inhabits travertine ponds inside the cave. This latter behaviour has been documented in several other *Xangoniscus* species (Cardoso et al. 2020; Campos-Filho et al. 2022b).

Xangoniscus jonasi López-Orozco, Bichuette & Campos-Filho, sp. nov.

https://zoobank.org/018645EB-FC2A-4CEA-B1B3-9EC60D23F2BA

Figs 1, 7–10

Type material. ***Holotype*** • 1 male (parts in slides) (LES 0030097), Bahia, Carinhanha, Gruna da Serra Solta cave, -13.510573, -43.75207, 24 October 2023, leg. JE Gallão.

Description. Maximum body length: male 6.5 mm. Body outline as in Figs 7A, B, 8A. Colourless (Fig. 7). Dorsal surface smooth, with scattered fringed scale setae (Figs 7A–E, 8B). Cephalon (Figs 7C, D, 8C) with large quadrangular antennary lobes; vertex with slightly lateral depression to fit antennae when extended backwards, profrons with V-shaped suprantennal line, not surpassing antennule insertion; eyes absent. Pereonite 1 epimera with distal corners not developed frontwards, posterior corners right-angled; pereonites 2–7 epimera gradually directed backwards, posterior corners progressively more acute; pleon narrower than pereon; pleonites 3–5 epimera posterior point not developed (Figs 7A, B, D, 8A). Telson with concave sides and rounded apex (Fig. 8D). Antennula (Fig. 8E) composed of three articles, proximal and distal articles subequal in length, second article short, distal article with eight very long aesthetascs. Antenna (Fig. 8F) short, not surpassing pereonite 3 when extended backwards; flagellum of equal length of fifth article of peduncle, composed of three articles subequal

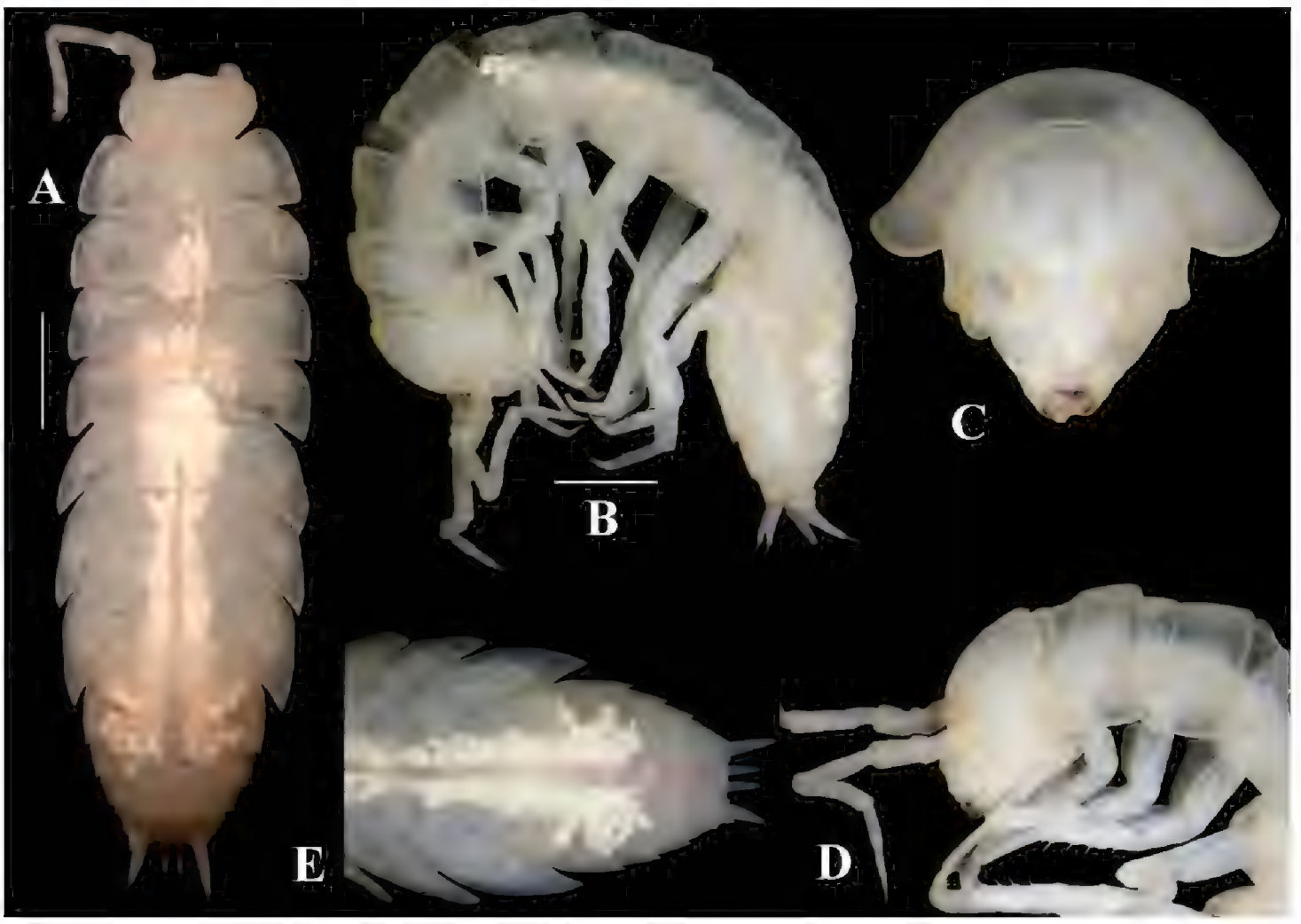

Figure 7. *Xangoniscus jonasi* López-Orozco, Bichuette & Campos-Filho, sp. nov. Male **A** habitus, dorsal view **B** habitus, lateral view **C** cephalon and pereonite 1, frontal view **D** cephalon and pereonites 1–2, lateral view **E** pereonite 7, pleon and telson, dorsal view. Scale bar: 1 mm.

in length. Left mandible (Fig. 8G) with two penicils; right mandible (Fig. 8H) with lacinia mobilis and one penicil. Maxillula (Fig. 8I) inner endite with three penicils; outer endite with 5+5 teeth, apically simple, and two plumose stalks. Maxilla (Fig. 8J) with setose and bilobate apex, outer lobe smaller. Maxilliped (Fig. 8K) basis enlarged on distal portion bearing fringe of fine setae; first article of palp with two tiny setae, distal articles with three tufts of setae; endite rectangular, outer and medial margins setose, apically with two triangular teeth and large rounded penicil. Uropod (Fig. 8D) branches short, endopod inserted proximally, exopod and endopod equal in length. Pereopods 1–7 (Fig. 9A–G) gradually elongated, with merus, carpus, and propodus bearing sparse setae; dactylus of one claw bearing many setae on inner and outer margins.

Male. Pereopod 1 (Fig. 9A) carpus with large antennal grooming brush. Pereopod 2–4 (Fig. 9B–D) merus with scales on sternal margin. Pereopods 5 and 7 (Fig. 9E, G) without distinct modifications. Pereopod 6 (Fig. 9F) carpus slightly grooved on sternal margin, propodus slightly enlarged on median portion. Genital papilla (Fig. 10B) lanceolate. Pleopod 1 (Fig. 10A) exopod trapezoidal, longer than wide, distal margin slightly convex, inner and outer margins bearing fringe of fine setae; endopod longer than exopod, with narrow basal article and flagelliform distal article; basipod distal margin elongate, longer than exopod, with semicircular apex, with fine and long setae.

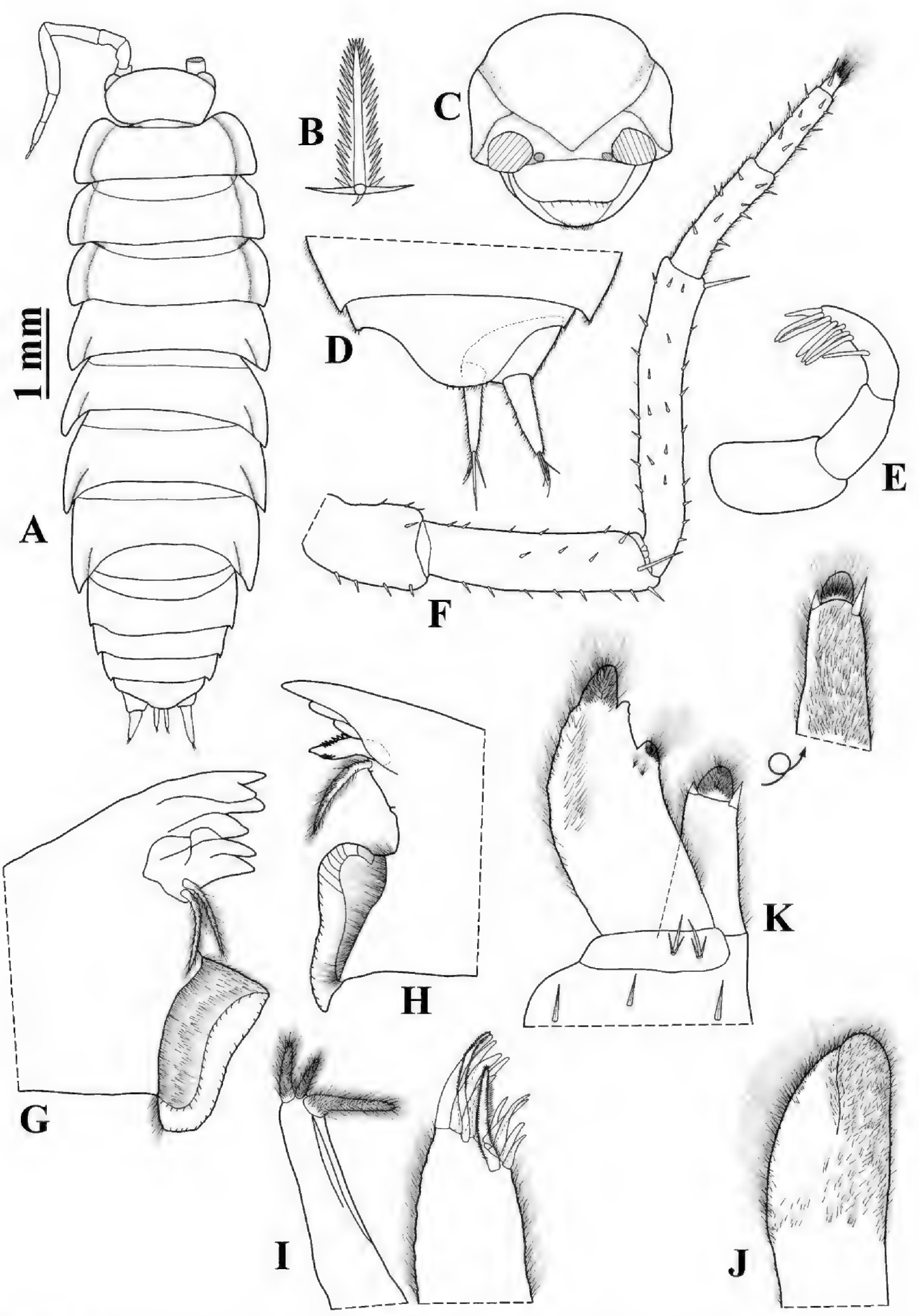

Figure 8. *Xangoniscus jonasi* López-Orozco, Bichuette & Campos-Filho, sp. nov. Male **A** habitus, dorsal view **B** dorsal scale-seta **C** cephalon, frontal view **D** telson and uropod **E** antennula **F** antenna **G** left mandible **H** right mandible **I** maxillula **J** maxilla **K** maxilliped, arrow illustrating the endite in caudal view.

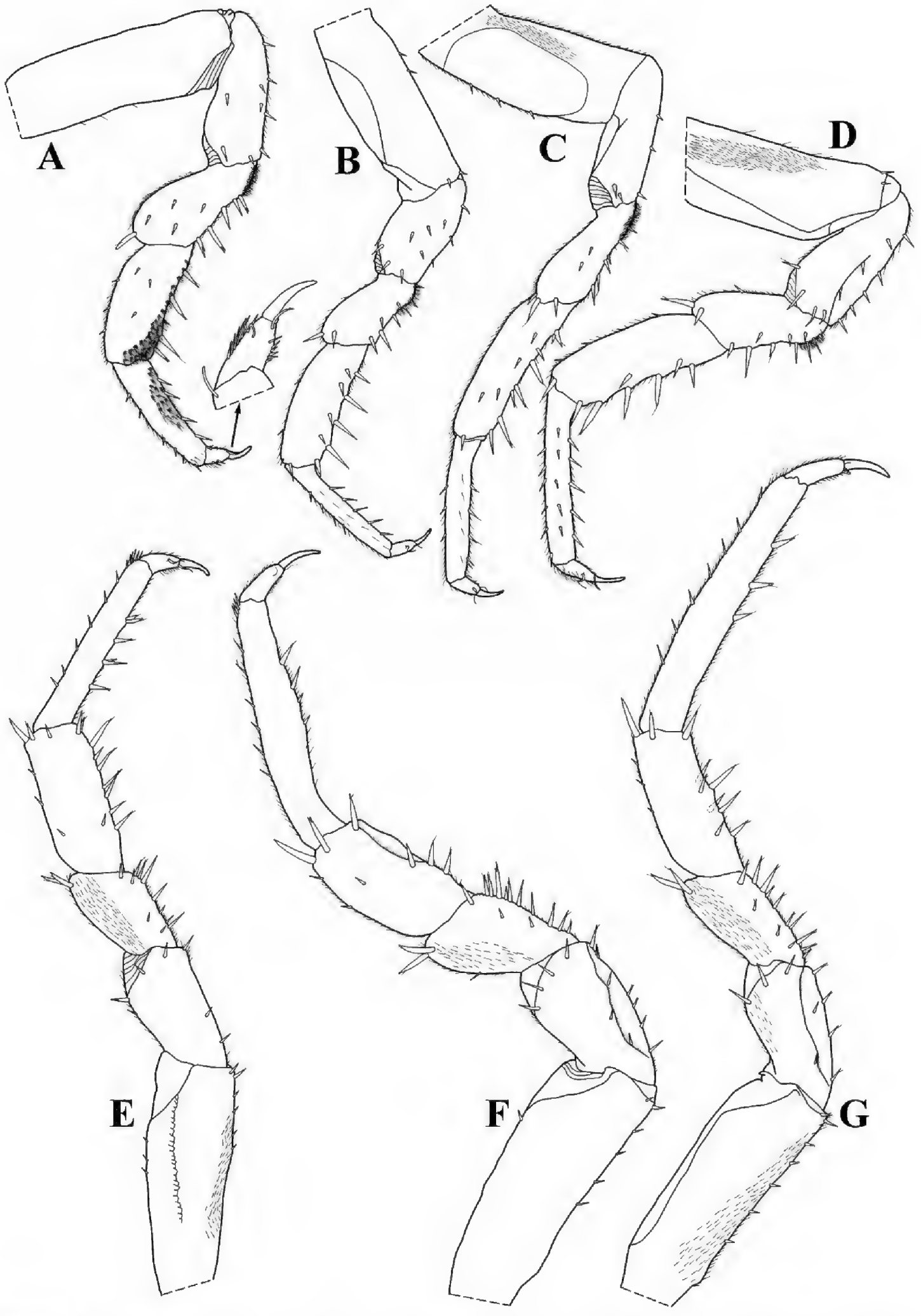

Figure 9. *Xangoniscus jonasi* López-Orozco, Bichuette & Campos-Filho, sp. nov. Male **A** pereopod 1 **B** pereopod 2 **C** pereopod 3 **D** pereopod 4 **E** pereopod 5 **F** pereopod 6 **G** pereopod 7.

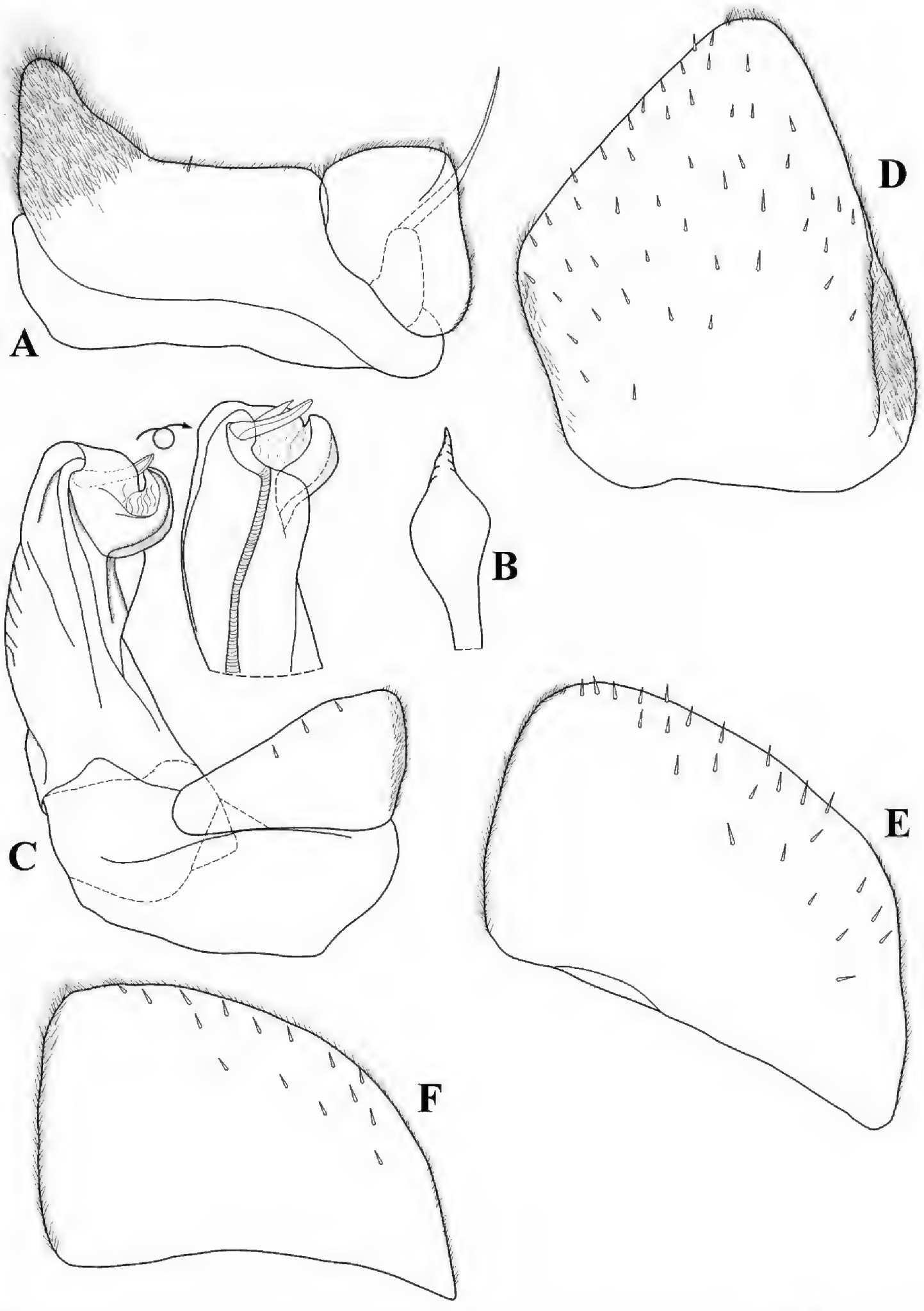

Figure 10. *Xangoniscus jonasi* López-Orozco, Bichuette & Campos-Filho, sp. nov. Male **A** pleopod 1 **B** genital papilla **C** pleopod 2 **D** pleopod 3 exopod **E** pleopod 4 exopod **F** pleopod 5 exopod.

Pleopod 2 (Fig. 10C) exopod trapezoidal, distal margin slightly convex bearing three setae; endopod of two articles, distal article about three times as long as proximal, with distal margin subquadrangular and apex rounded, with transversal process in V-like on apex in ventral view. Pleopod 3 (Fig. 10D) exopod triangular, longer than wide, covering pleopods 1 and 2, fringed with short setae. Pleopod 4 and 5 (Fig. 10E, F) exopods trapezoidal, wider than long, with margins bearing several short setae.

Etymology. The new species is named after Jonas Kahnwald, the protagonist of the "Dark" series, who explores caves to travel through time and space. The epithet "*jonasi*" is a tribute to the isolation and sense of separation from time and space that caves represent, evoking the central theme of "Dark". The species reflects extreme adaptation to dark depths, just as Jonas adapts to the complexities and paradoxes of time.

Distribution. Presently known only from Gruna da Serra Solta cave in the Serra do Ramalho karst area, state of Bahia, northeastern Brazil (Fig. 1).

Remarks. *Xangoniscus jonasi* sp. nov. differs from all other species of the genus in having the antennula with eight long aesthetascs (*vs.* two in *X. aganju*, *X. lapaensis*, and *X. odara*, three in *X. ibiracatuensis*, *X. lundi* and *X. santinhoi*, four in *X. dagua*, four or five in *X. ceci*, five in *X. loboi*, six in *X. itacarambiensis*, twelve in *X. chaimowiczi* sp. nov.), pleopod 1 basipod distal margin semicircular apex, longer than exopod (*vs.* simples and shorter than exopod in *X. lundi*, *X. dagua*, *X. ceci*, *X. ibiracatuensis*, *X. itacarambiensis*, *X. loboi*, *X. odara*, *X. santinhoi*, acute and longer than exopod in *X. chaimowiczi* sp. nov., *X. lapaensis* and *X. aganju*).

Natural history. The species showed low abundance (only one individual caught along the cave). The only individual of *X. jonasi* sp. nov. captured was found in the aphotic zone on a very wet, muddy substrate, under the cracks formed by the stream current, just a few meters from a pond (Fig. 1C).

Xangoniscus antiquus López-Orozco, Carpio-Díaz & Campos-Filho, sp. nov.

https://zoobank.org/A6A94235-318F-4C1B-9429-3B16B83EF0AB

Figs 1, 11–14

Type material. ***Holotype*** • 1 male (MZUSP 29513), Bahia, Canápolis, Gruta da Represa cave, -13.08105, -44.145703, February 1986, leg. A. Auler. ***Paratypes*** • 1 male (parts in slides) (MZUSP 29513), same data as holotype.

Description. Maximum body length: male 7.8 mm. Body outline as in Figs 11A, B, 12A. Colourless (Fig. 11). Dorsal surface smooth, with scattered fringed scale setae (Figs 11, 12B). Cephalon (Figs 11C, 12C) with large quadrangular antennary lobes; vertex with slightly lateral depression to fit antennae when extended backwards, profrons with V-shaped suprantennal line, not surpassing antennule insertion; eyes absent. Pereonite 1 epimera with distal corners developed frontwards, posterior corners right-angled; pereonites 2–7 epimera gradually directed backwards, posterior corners

Figure 11. *Xangoniscus antiquus* López-Orozco, Carpio-Díaz & Campos-Filho, sp. nov. Male **A** habitus, dorsal view **B** habitus, lateral view **C** cephalon and pereonite 1, frontal view **D** pereonite 7, pleon and telson, dorsal view. Scale bar: 1 mm.

progressively more acute; pleon narrower than pereon; pleonites 3–5 epimera posterior point developed (Figs 11A, B, 12A). Telson with concave sides and an almost straight apex (Fig. 12D). Antennula (Fig. 12E) composed of three articles, proximal and distal articles subequal in length, second article short, distal article with eight very long aesthetascs. Antenna (Fig. 12F) short, not surpassing pereonite 2 when extended backwards; flagellum shorter than of fifth article of peduncle, composed of three articles subequal in length. Left mandible (Fig. 12G) with two penicils; right mandible (Fig. 12H) with lacinia mobilis and one penicil. Maxillula (Fig. 12I) inner endite with three penicils; outer endite with 5+5 teeth, apically simple, and two plumose stalks. Maxilla (Fig. 12J) with setose and bilobate apex, outer lobe smaller. Maxilliped (Fig. 12K) basis enlarged on distal portion bearing fringe of fine setae; first article of palp with two tiny setae, distal articles with three tufts of setae; endite rectangular, outer and medial margins setose, apically with two triangular teeth and large rounded penicil. Uropod (Fig. 12D) branches short and inserted at same level, exopod slightly longer than endopod. Pereopods 1–7 (Fig. 13A–G) gradually elongated, with merus, carpus, and propodus bearing sparse setae; dactylus of one claw bearing many setae on outer margin.

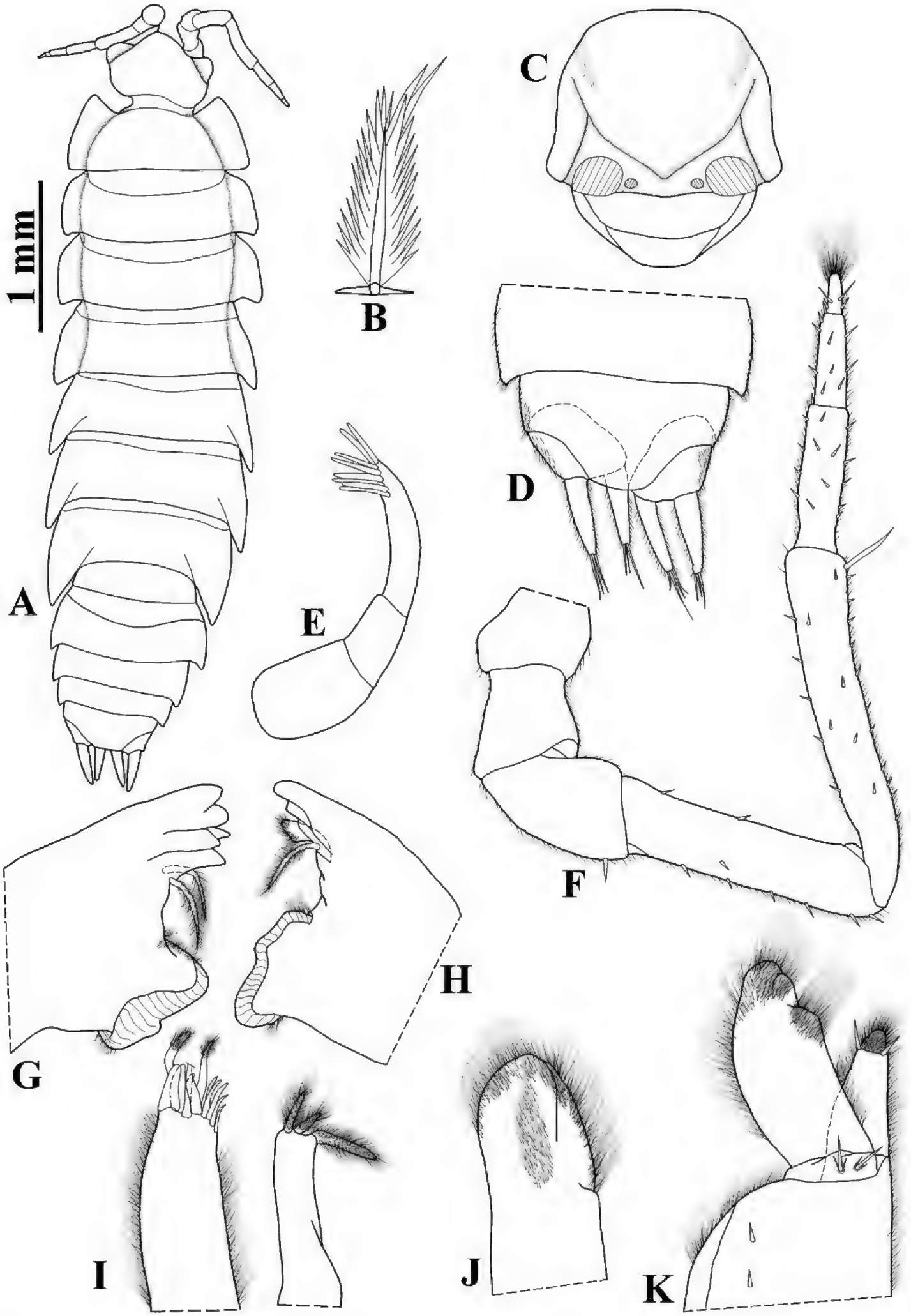

Figure 12. *Xangoniscus antiquus* López-Orozco, Carpio-Díaz & Campos-Filho, sp. nov. Male **A** habitus, dorsal view **B** dorsal scale-seta **C** cephalon, frontal view **D** telson and uropod **E** antennula **F** antenna **G** left mandible **H** right mandible **I** maxillula **J** maxilla **K** maxilliped, arrow illustrating the endite in caudal view.

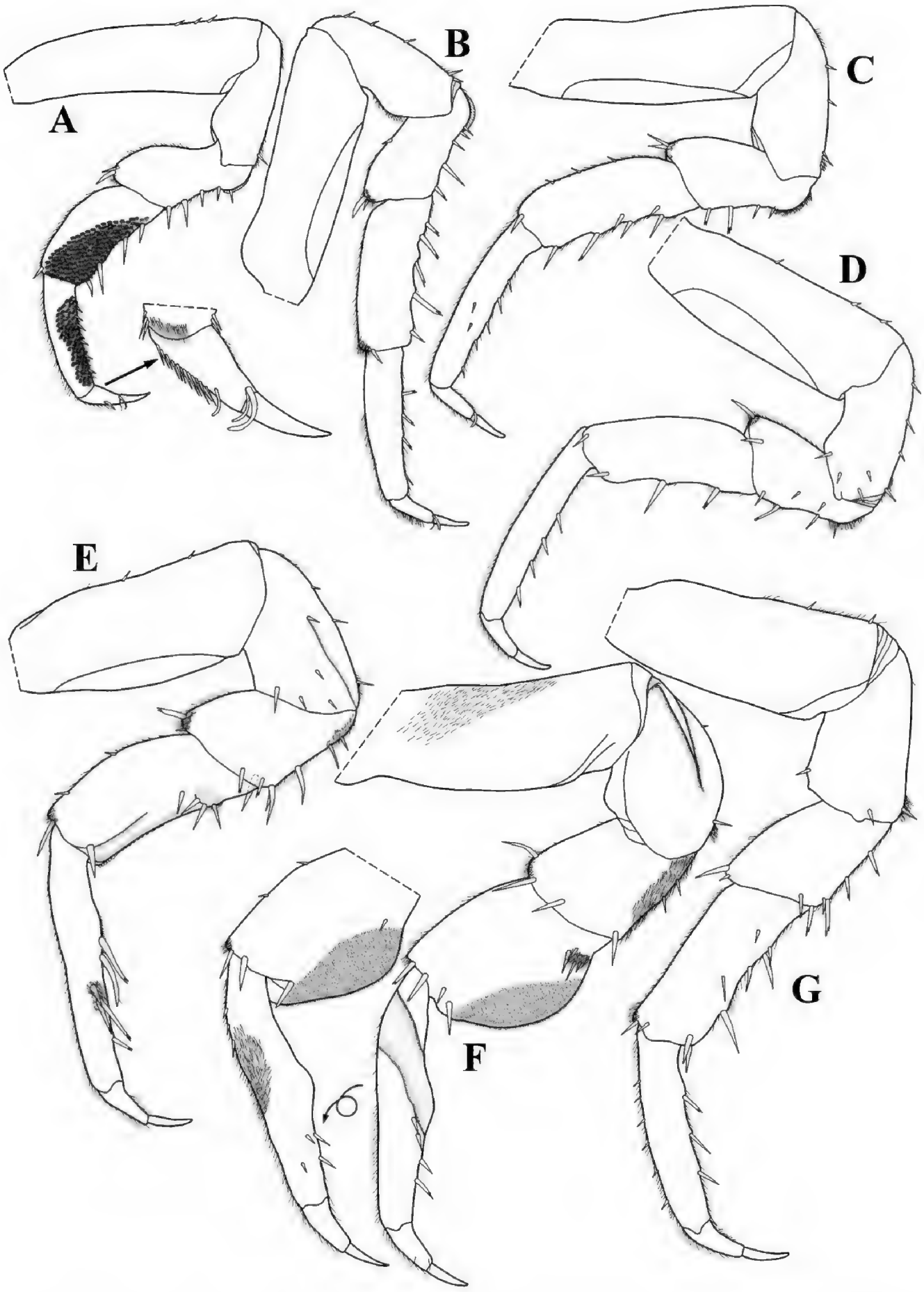

Figure 13. *Xangoniscus antiquus* López-Orozco, Carpio-Díaz & Campos-Filho, sp. nov. Male **A** pereopod 1 **B** pereopod 2 **C** pereopod 3 **D** pereopod 4 **E** pereopod 5 **F** pereopod 6 **G** pereopod 7.

Male. Pereopods 1–6 (Fig. 5A–F) merus with proximal portion bearing fringed scales and thin setae on sternal margin. Pereopod 1 (Fig. 13A) carpus with large antennal grooming brush. Pereopod 5 (Fig. 13E) carpus with small lobe on proximal sternal margin. Pereopod 6 (Fig. 13F) ischium enlarged with flattened sternal part;

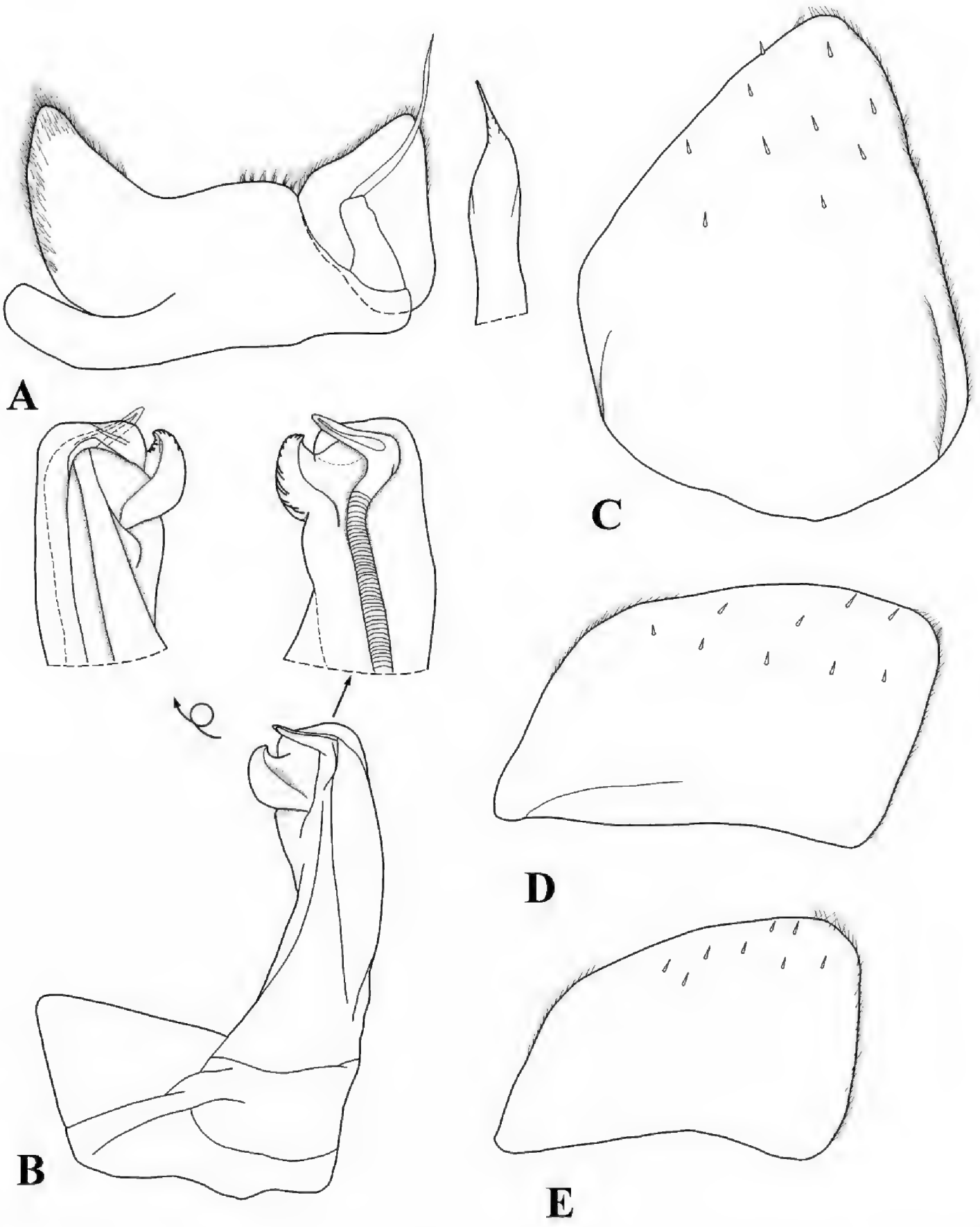

Figure 14. *Xangoniscus antiquus* López-Orozco, Carpio-Díaz & Campos-Filho, sp. nov. Male **A** pleopod 1 **B** genital papilla **C** pleopod 2 **D** pleopod 3 exopod **E** pleopod 4 exopod **F** pleopod 5 exopod.

carpus enlarged, rostral portion bearing dense field of tiny lobules; propodus with central part enlarged, with longitudinal furrow in ventral view, and field of short setae on dorsal part. Pereopod 7 (Fig. 13G) without distinct modifications. Genital papilla (Fig. 14A) lanceolate. Pleopod 1 (Fig. 14A) exopod subtriangular, longer than wide, inner and outer margins bearing fringe of fine setae; endopod longer than exopod, with narrow basal article and flagelliform distal article; basipod distal margin elongate

and semicircular apex, slightly longer than exopod, with fine and long setae. Pleopod 2 (Fig. 14B) exopod trapezoidal, distal margin almost straight; endopod of two articles, distal article about three times as long as proximal, with distal margin subquadrangular and apex rounded, with transversal process in V-like on apex in ventral view. Pleopod 3 (Fig. 14C) exopod triangular, longer than wide, covering pleopods 1 and 2, fringed with short setae. Pleopod 4 and 5 (Fig. 14D, E) exopods trapezoidal, wider than long, with margins bearing several short setae.

Etymology. Latin, *antiquus* = old. The new species name refers to the long period of time that the samples remained preserved until their description. Perhaps this material represents the first specimens of *Xangoniscus* collected in Brazil.

Distribution. Presently known only from Gruta da Represa cave, in the state of Bahia, northeastern Brazil (Fig. 1).

Remarks. *Xangoniscus antiquus* sp. nov. resembles *X. chaimowiczi* sp. nov. in the modifications on male pereopods and number of articles on flagellum of antenna; however, it differs in the number of aesthetascs on antennula (eight *vs.* twelve in *X. chaimowiczi* sp. nov.), telson apex (almost straight *vs.* rounded apex in *X. chaimowiczi* sp. nov.), and basipod distal margin (semicircular apex, slightly longer than exopod *vs.* acute apex, longer than exopod in *X. chaimowiczi* sp. nov.).

Discussion

The genus *Xangoniscus* was erected by Campos-Filho et al. (2014) to include the troglobitic amphibious species *X. aganju* from Gruna do Mandiaçu cave, Carinhanha, state of Bahia. The following characters were proposed as diagnostic for the genus: pleonites 3–5 with well-developed epimera, with visible posterior points; antennule with long apical aesthetascs; antenna with flagellum of three articles; male pleopod 1 exopod shorter than endopod. Subsequent studies, including the species described here (see also Campos-Filho et al. 2015, 2022b; Bastos-Pereira et al. 2017; Cardoso et al. 2020), *X. antiquus* sp. nov., *X. ceci*, *X. dagua*, *X. itacarambiensis*, *X. ibiracatuensis*, *X. jonasi* sp. nov., *X. loboi*, *X. lundi*, *X. odara*, *X. santinhoi*, and *X. chaimowiczi* sp. nov. do not present the epimera of pleonites 3–5 developed; the aesthetascs of the distal article of the antennula are short in *X. dagua*, *X. ceci*, *X. itacarambiensis*, and *X. lundi*; and the number of articles in the flagellum of the antenna varies between four and six across different species. In addition, the description of *X. ceci* mentioned that the male pleopod 1 endopod is equal in length to the exopod; the illustrations showed that the endopod is shorter than the exopod (see fig. 10E in Cardoso et al. 2020). Considering the above, the mentioned characters must be modified as follows: pleonites 3–5 epimera well developed or short with small posterior points directed backward; antennule with long or short apical aesthetascs; antenna with flagellum of three to six articles; male pleopod I exopod longer or shorter than endopod. To date, two morphological characteristics can be defined as synapomorphies of *Xangoniscus*: cephalon with a transversal groove on the vertex along the frontal margin and the complex apex of the male pleopod 2 endopod (Campos-Filho et al. 2014). Moreover, a

taxonomically important characteristic is the shape and size of the distal margin of the basipodite of male pleopod 1, which allows differentiation between some species.

Species of the genus *Xangoniscus* have been recorded in travertine pools and streams formed by infiltration of water, inhabiting microhabitats composed of rocky substrates, silty sediment, sand, and decomposing plant material (Campos-Filho et al. 2015, 2022b; Bastos-Pereira et al. 2017; Cardoso et al. 2020). *Xangoniscus chaimowiczi* sp. nov. and *Xangoniscus jonasi* sp. nov. follow this pattern and occupy similar microhabitats in the caves they inhabit. However, the specific microhabitat of *Xangoniscus antiquus* sp. nov. in Gruta da Represa cave remains unknown. Therefore, further research into these subterranean environments is needed to better understand the ecology and habits of the species that live there.

Regarding the current distribution of the genus *Xangoniscus*, it is restricted to limestone caves of the Bambui Geomorphological Group located within semiarid environments of the Chacoan subregion, in the biogeographic provinces of Cerrado, Caatinga, and Southern Espinhaco (sensu Morrone et al. 2014, 2022), in the states of Bahia and Minas Gerais (Fig. 1). This distribution suggests that in caves with water or tributaries of the São Francisco River basin within this geomorphological group, there is a high potential for the occurrence of species of this genus. However, macroecological studies are needed to elucidate the geographic patterns of this genus, along with increased sampling efforts in other caves in the area. The records of *X. antiquus* sp. nov. and *X. chaimowiczi* sp. nov. extend the known distribution of this genus to the northern part of this geological formation. To date, only *X. aganju* has been reported from multiple caves (Fig. 1); however, as noted by Campos-Filho et al. (2019), molecular studies could uncover potential cryptic diversity within the species.

Among the three species described here, *Xangoniscus* now includes 13 troglobitic amphibious species, making it the second most species-rich genus of Styloniscidae in Brazil. Among these species, only five are found in national conservation units in Minas Gerais (*X. dagua*, *X. itacarambiensis*, *X. lundi*, *X. odara*, and *X. santinhoi*) (Fig. 1); nevertheless, they are threatened by uncontrolled tourism and the expansion of agricultural activities (Gallão and Bichuette 2018). Special attention should be directed toward the remaining species, particularly in the state of Bahia, where there are no conservation areas dedicated to the protection and management of speleological resources in the studied caves. Areas such as Serra do Ramalho, which is considered a hotspot of subterranean biodiversity (Trajano et al. 2016), should be prioritised for proposals aimed at creating new legally protected areas. Several caves are affected by water extraction, a situation that has been documented in various studies (Gallão and Bichuette 2018; Cardoso et al. 2022), including at Gruna da Serra Solta (Fig. 2C). This activity could negatively affect populations of species with amphibious habits. Regarding the Gruta do Padre cave, Auler and Rubbioli (2019) noted that it has a good conservation status. Since the Tatus II project, an experiment conducted in 1987 where a group of speleologists stayed for 21 days inside the Gruta do Padre cave, the cave has only been sporadically visited by researchers, and its resources remain unexploited (Chaimowicz 1987). With the description of *X. chaimowiczi* sp. nov., we

increased the number of troglobitic species that inhabit Gruta do Padre cave to six, the second species of Oniscidea described from this locality: *Chaimowiczia tatus* Cardoso, Bastos-Pereira, Souza & Ferreira, 2021 (Oniscidea), *Coarazuphium tessai* (Godoy & Vanin, 1990) (Coleoptera), *Spelaeogammarus santanensis* Koenemann & Holsinger, 2000 (Amphipoda), *Phaneromerium cavernicolum* Golovatch & Wytwer, 2004 (Polydesmida) (Godoy and Vanin 1990; Koenemann and Holsinger 2000; Golovatch and Wytwer 2004; Cardoso et al. 2021).

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References

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JDM, Sparovek G (2013) Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22(6): 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Anderson LE (1954) Hoyer's Solution as a Rapid Permanent Mounting Medium for Bryophytes. The Bryologist 57: e242. https://doi.org/10.2307/3240091

Auler AS, Rubbioli EL (2019) Gruta do Padre. In: Rubbioli E, Auler A, Menin D, Brandi R (Eds) Cavernas – Atlas do Brasil Subterrâneo. ICMBio, Brasilia, DF, 82–87.

Bastos-Pereira R, Souza LA, Ferreira RL (2017) A new amphibious troglobitic styloniscid from Brazil (Isopoda, Oniscidea, Synocheta). Zootaxa 4294(2): 292–300. https://doi.org/10.11646/zootaxa.4294.2.11

Bastos-Pereira R, Souza LA, Sandi BDS, Ferreira RL (2022) A new species of *Spelunconiscus* (Isopoda: Oniscidea: Styloniscidae) for Brazilian caves: new record for the type species and an emended diagnosis for the genus. Nauplius 30: e2022018. https://doi.org/10.1590/2358-2936e2022018

Bedek J, Taiti S, Gottstein S (2011) Catalogue and atlas of cave-dwelling terrestrial isopods (Crustacea: Oniscidea) from Croatia. Natura Croatica 20(2): 237–354. https://hrcak.srce.hr/75047

Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF (2018) Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific Data 5: e180214. https://doi.org/10.1038/sdata.2018.214

Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF (2020) Publisher Correction: Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific Data 7: e274. https://doi.org/10.1038/s41597-020-00616-w

Boyko CB, Bruce NL, Hadfield KA, Merrin KL, Ota Y, Poore GCB, Taiti S (2024 [Onwards]) Styloniscidae Vandel, 1952. Accessed by World Marine, Freshwater and Terrestrial Isopod Crustaceans database. https://marinespecies.org/aphia.php?p=taxdetails&id=248319 [Accessed on 27 August 2024]

Campos-Filho IS, Araujo PB, Bichuette ME, Trajano E, Taiti S (2014) Terrestrial isopods (Crustacea: Isopoda: Oniscidea) from Brazilian caves. Zoological Journal of the Linnean Society 172(2): 360–425. https://doi.org/10.1111/zoj.12172

Campos-Filho IS, Mise KM, Sessegolo GC (2015) A new species of *Trichorhina* Budde-Lund, 1908 (Isopoda: Oniscidea: Platyarthridae) from Paraná caves, southern Brazil. Nauplius 23: 112–119. https://doi.org/10.1590/S0104-64972015002324

Campos-Filho IS, Bichuette ME, Taiti S (2016) Three new species of terrestrial isopods (Crustacea, Isopoda, Oniscidea) from Brazilian caves. Nauplius 24: e2016001. https://doi.org/10.1590/2358-2936e2016001

Campos-Filho IS, Cardoso GM, Aguiar JO (2018) Catalogue of terrestrial isopods (Crustacea, Isopoda, Oniscidea) from Brazil: an update with some considerations. Nauplius 26: e2018038. https://doi.org/10.1590/2358-2936e2018038

Campos-Filho IS, Fernandes CS, Cardoso GM, Bichuette ME, Aguiar JO, Taiti S (2019) Two new species and new records of terrestrial isopods (Crustacea, Isopoda, Oniscidea) from Brazilian caves. Zootaxa 4564(2): 422–448. https://doi.org/10.11646/zootaxa.4564.2.6

Campos-Filho IS, Fernandes CS, Cardoso GM, Bichuette ME, Aguiar JO, Taiti S (2020) New species and new records of terrestrial isopods (Crustacea, Isopoda, Oniscidea) of the families Philosciidae and Scleropactidae from Brazilian caves. European Journal of Taxonomy 606: 1–38. https://doi.org/10.5852/ejt.2020.606

Campos-Filho IS, Gallo JS, Gallão JE, Torres DF, Carpio-Díaz YM, López-Orozco CM, Borja-Arrieta R, Taiti S, Bichuette ME (2022a) Expanding the knowledge on the diversity of the cavernicolous Styloniscidae Vandel, 1952 (Oniscidea, Synocheta) from Brazil, with

descriptions of two new species from the semiarid karst regions. ZooKeys 1101: 35–55. https://doi.org/10.3897/zookeys.1101.79043

Campos-Filho IS, Gallo JS, Gallão JE, Torres DF, Horta L, Carpio-Díaz YM, López-Orozco CM, Borja-Arrieta R, Aguiar JO, Bichuette ME (2022b) Unique and fragile diversity emerges from Brazilian caves – two new amphibious species of *Xangoniscus* Campos-Filho, Araujo & Taiti, 2014 (Oniscidea, Styloniscidae) from Serra do Ramalho karst area, state of Bahia, Brazil. Subterranean Biology 42: 1–22. https://doi.org/10.3897/subtbiol.42.75725

Campos-Filho IS, Cardoso GM, Bichuette ME (2022c) Isopoda, Oniscidea. In: Zampaulo RA, Prous X (Eds) Fauna cavernícola do Brasil. Editora Rupestre, Belo Horizonte, Brazil, 363–387.

Campos-Filho IS, Sfenthourakis S, Gallo JS, Gallão JE, Torres DF, Chagas-Jr A, Horta L, Carpio-Díaz YM, López-Orozco CM, Borja-Arrieta R, Araujo PB, Taiti S, Bichuette ME (2023a) Shedding light into Brazilian subterranean isopods (Isopoda, Oniscidea): expanding distribution data and describing new taxa. Zoosystema 45(19): 531–599. https://doi.org/10.5252/zoosystema2023v45a19

Campos-Filho IS, López-Orozco CM, Carpio-Díaz YM, Borja-Arrieta RL, Gallão JE, Taiti S, Sfenthourakis S, Bichuette ME (2023b) Everything is similar, everything is different! *Trichorhina* (Oniscidea, Platyarthridae) from Brazilian caves, with descriptions of 11 new species. Biota Neotropica 23: e20231545. https://doi.org/10.1590/1676-0611-BN-2023-1545

Cardoso GM, Bastos-Pereira R, Souza LA, Ferreira RL (2020a) New troglobitic species of *Xangoniscus* (Isopoda: Styloniscidae) from Brazil, with notes on their habitats and threats. Zootaxa 4819(1): 084–108. https://doi.org/10.11646/zootaxa.4819.1.4

Cardoso GM, Bastos-Pereira R, Souza LA, Ferreira RL (2020b) New cave species of *Pectenoniscus* Andersson, 1960 (Isopoda: Oniscidea: Styloniscidae) and an identification key for the genus. Nauplius 28: e2020039. https://doi.org/10.1590/2358-2936e2020039

Cardoso GM, Bastos-Pereira R, Souza LA, Ferreira RL (2021) *Chaimowiczia*: a new Iuiuniscinae genus from Brazil (Oniscidea, Synocheta, Styloniscidae) with the description of two new troglobitic species. Subterranean Biology 39: 45–62. https://doi.org/10.3897/subtbiol.39.65305

Cardoso GM, Bastos-Pereira R, Ferreira R (2023) Cave-dwellers *Diploexochus* (Isopoda, Armadillidae): new species and new records of the genus from Brazil. Nauplius 31: e2023008. https://doi.org/10.1590/2358-2936e2023008

Cardoso GM, Ferreira RL (2023a) New troglobitic species of *Benthana* Budde-Lund, 1908 and Benthanoides Lemos de Castro, 1958 from iron-ore caves and their important record in the Amazon biome (Crustacea: Isopoda: Philosciidae). Zootaxa 4(27): 548–562. https://doi.org/10.11646/zootaxa.5319.4.5

Cardoso GM, Ferreira RL (2023b) New troglobitic species of *Pectenoniscus* Andersson, 1960 (Isopoda: Oniscidea: Styloniscidae) from Bahia state, Brazil. Studies on Neotropical Fauna and Environment 59: 202–223. https://doi.org/10.1080/01650521.2023.2230735

Chaimowicz F (1987) Operação Tatus II. Experimento de permanência subterrânea. Bioespeleologia. Informativo SBE 16:5.

Dimitriou AC, Taiti S, Sfenthourakis S (2019) Genetic evidence against monophyly of Oniscidea implies a need to revise scenarios for the origin of terrestrial isopods. Scientific Reports 9: e18508. https://doi.org/10.1038/s41598-019-55071-4

Gallão JE, Bichuette ME (2018) Brazilian obligatory subterranean fauna and threats to the hypogean environment. ZooKeys 746: 1–23. https://doi.org/10.3897/zookeys.746.15140

Godoy NM, Vanin SA (1990) *Parazuphium tessai*, sp. nov., a new cavernicolous beetle from Bahia, Brazil (Coleoptera, Carabidae, Zuphiini). Revista Brasileira de Entomologia 34: 795–799.

Golovatch S, Wytwer J (2004) The South American Millipede Genus *Phaneromerium* Verhoeff, 1941, with the description of a new cavernicolous species from Brazil (Diplopoda: Polydesmida: Fuhrmannodesmidae). Annales Zoologici 3(54): 1–4.

Javidkar M, Cooper SJB, King RA, Humphreys WF, Austin A (2015) Molecular phylogenetic analyses reveal a new southern hemisphere oniscidean family (Crustacea: Isopoda) with a unique water transport system. Invertebrate Systematics 29: 554–577. https://doi.org/10.1071/IS15010

Koenemann S, Holsinger JR (2000) Revision of the subterranean amphipod genus *Spelaeogammarus* (Bogidiellidae) from Brazil, including descriptions of three new species and considerations of their phylogeny and biogeography. Proceedings of the Biological Society of Washington 113(1): 104–123.

López-Orozco CM, Carpio-Díaz YM, Borja-Arrieta R, Navas GR, Campos-Filho IS, Taiti S, Mateos M, Olazaran A, Caballero IC, Jotty K, Gómez-Estrada H, Hurtado L (2022) A glimpse into remarkable unkown diversity of oniscideans along the Caribbean coasts revealed on a tiny island. European Journal of Taxonomy 793: 1–50. https://doi.org/10.5852/ejt.2022.793.1643

López-Orozco CM, Campos-Filho IS, Gallo JS, Gallao JE, Carpio-Díaz YM, Borja-Arrieta R, Bichuette ME (2024a) Iron-isops: new records and new species of terrestrial isopods (Isopoda, Oniscidea) from Brazilian Amazon iron ore caves. European Journal of Taxonomy 921: 116–135. https://doi.org/10.5852/ejt.2024.921.2421

López-Orozco CM, Campos-Filho IS, Cordeiro LM, Gallao JE, Carpio-Díaz YM, Borja-Arrieta R, Bichuette ME (2024b) First amphibius Crinocheta (Isopoda, Oniscidea) from Neotropics with a troglobitic status: a relictual distribution. Zookeys 1192: 9–27. https://doi.org/10.3897/zookeys.1192.114230

Montesanto G (2015) A fast GNU method to draw accurate scientific illustrations for taxonomy. ZooKeys 515: 191–206. https://doi.org/10.3897/zookeys.515.9459

Montesanto G (2016) Drawing setae: a GNU way for digital scientific illustrations. Nauplius 24: e2016017. https://doi.org/10.1590/2358-2936e2016017

Morrone JJ (2014) Biogeographical regionalisation of the Neotropical region. Zootaxa 3782: 1–110. https://doi.org/10.11646/zootaxa.3782.1.1

Morrone JJ, Escalante T, Rodríguez-Tapia G, Carmona A, Arana M, Mercado-Gómez JD (2022) Biogeographic regionalization of the Neotropical region: new map and shapefile. Anais da Academia Brasileira de Ciências 94(1): e20211167. https://doi.org/10.1590/0001-3765202220211167

Reboleira ASPS, Goncalves F, Oromí P, Taiti S (2015) The cavernicolous Oniscidea (Crustacea: Isopoda) of Portugal. European Journal of Taxonomy 161: 1–61. https://doi.org/10.5852/ejt.2015.161

Schmalfuss H (2003) World catalog of terrestrial isopods (Isopoda: Oniscidea). Stuttgarter Beiträge zur Naturkunde, Serie A 654: 1–341.

Sfenthourakis S, Taiti S (2015) Patterns of taxonomic diversity among terrestrial isopods. ZooKeys 515: 13–25. https://doi.org/10.3897/zookeys.515.9332

Souza LA, Ferreira RL, Senna AR (2015) Amphibious shelter-builder Oniscidea species from the New World with description of a new subfamily, a new genus and a new species from Brazilian Cave (Isopoda, Synocheta, Styloniscidae). PloS one 10(5): e0115021. https://doi.org/10.1371/journal.pone.0115021

Tabacaru I, Giurginca A (2013) Cavernicolous Oniscidea of Romania. Travaux de l'Institut de Speologie "Emile Racovitza" 42: 3–26.

Taiti S (2004) Crustacea: Isopoda: Oniscidea (woodlice). In: Gunn J (Ed.) Encyclopedia of caves and karst science. Fitzroy Dearborn, Taylor and Francis Group, New York. United States. 547–551.

Taiti S, Gruber GA (2008) Cave-dwelling terrestrial isopods from Southern China (Crustacea, Isopoda, Oniscidea), with descriptions of four new species. In: Latella L, Zorzin R (Eds) Research in South China karsts. Memorie del Museo Civico di Storia Naturale di Verona, Monografie Naturalistiche, 101–123.

Taiti S, Xue Z (2012) The cavernicolous genus *Troglоniscus* nomem novum, with descriptions of four new species from southern China (Crustacea, Oniscidea, Styloniscidae). Tropical Zoology 25(4): 183–209. https://doi.org/10.1080/03946975.2012.751240

Trajano E, Carvalho MR (2017) Towards a biologically meaningful classification of subterranean organisms: a critical analysis of the Schiner-Racovitza system from a historical perspective, difficulties of its application and implications for conservation. Subterranean Biology 22: 1–26. https://doi.org/10.3897/subtbiol.22.9759

Trajano E, Gallão JE, Bichuette ME (2016) Spots of high diversity of troglobites in Brazil: the challenge of measuring subterranean diversity. Biodiversity and Conservation 25(10): 1805–1828. https://doi.org/10.1007/s10531-016-1151-5